CLOSURE AS A SCIENTIFIC CONCEPT AND ITS APPLICATION TO ECOSYSTEM ECOLOGY AND THE SCIENCE OF THE BIOSPHERE

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Closure is a key concept in the physical sciences that has infrequently been used in ecology. The paper reviews closure to the flow of matter and energy (adiabatic walls) and closure to the flow of matter (diathermal walls). A system with rigid adiabatic walls will degrade eventually to chemical equilibrium, a state of maximum entropy. A third type of closure involves semi-permeable walls permitting the flow of one or more types of chemicals. These closure concepts were important to the development of classical thermodynamics and statistical mechanics in the 19^{th} and 20^{th} centuries. "Equilibrium" is often used to describe a time independent steady state. This usage leads to confusion, because equilibrium has such a precise meaning in thermal physics. All living systems are far-from-equilibrium and life cannot persist without the flow of energy. The Earth is an almost materially-closed system. Only a small amount of cosmic matter is captured by the earth's gravitational field and only a small fraction of lighter elements escape that field. The earth receives photon flux from the sun and generates thermal energy from the planetary decay of radioisotopes. A hypothesis can be advanced that the planetary biosphere exists in part because of material closure due to gravitation. In the science of ecology partial material closure has been introduced in limnology and island ecology. This has advanced biogeographical theory and systems ecology. The development of the past half century of first balanced aquaria and terrariums, and then partially materially-closed microcosms and mesocosms has also greatly aided the development of ecology as an experimental rather than merely descriptive science. All the above systems are open atmospherically, and often have some water and nutrient inputs. The development of truly materially closed man-made systems offers further scope for the development of experimental ecology. The paper reviews and defines the various types of closed ecological systems: Class 1: natural planetary biospheres (like the EarthŠs); and Class 2: man-made systems which range from laboratory microbial ecospheres, to ones capable of human life support: Controlled Environmental Life Support Systems (CELSS such as are being developed by NASA and the European Space Agency), Closed Ecological Systems (such as Bios-3 at the Institute of Biophysics in Krasnoyarsk, Russia and the Biosphere 2 Test Module) to mini-biospheric systems with a complexity of internal ecosystems (e.g. Biosphere 2 and the Closed Ecology Experimental Facility, CEEF, in Japan).